# ANIMAL-SEDIMENT INTERACTIONS RELEVANT TO SHALLOW-WATER BOUNDARY-LAYER FLOWS AND SEDIMENT TRANSPORT

Cheryl Ann Butman
Applied Ocean Physics and Engineering Department
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(508) 289-2442
cbutman@whoi.edu

Award Number N00014-96-0946

## LONG-TERM GOAL

Models that provide estimates of sediment-transport rates and directions use, as input, a modest amount of information from the field. Such models possess an inherent, untested assumption that only physical processes and abiotic characteristics of the bed govern sediment movement. This study evaluates this assumption by measuring the magnitude of benthic-biological effects on nearbed flows and sediment transport in the kinds of environments of most immediate interest to the Navy -- sands, sand-mud mixtures and high flows that occur in very shallow water. The long-term goals of this research are to identify (1) conditions where existing, abiotic, sediment-transport models would make reasonably accurate predictions, and (2) the key, biologically relevant variables which should be incorporated into the models for conditions where biology is important. Ultimately, this research would contribute to a new generation of models that could provide sediment-transport predictions which are meaningful for both biotic and abiotic conditions.

## OBJECTIVES

The objectives of this study are to obtain estimates of the seafloor area covered by dense assemblages of organisms that are likely to affect sediment transport in high-energy, very shallow water (< 15 m), sandy environment and to quantify the effects of these organisms on near-bed flows and sediment transport in a laboratory flume The project consists of a technology-development (FY96), a field (FY97) and a laboratory-flume (FY98) component. The specific objective of the research conducted during FY97 was to map repeatedly, with meter-scale resolution, the distribution of dense, surface- visible benthic organisms over a kilometer-scale region of the bottom at an exposed, high-energy, sandy site.

## APPROACH

This study focusses on “large signals” -- that is, it is designed to document distributions in the field and to measure specific effects in the flume of those biological assemblages expected to have the largest influence on near-bed flows and sediment transport. Examples of such assemblages in nearshore sandy sediments are dense beds of sand dollars, tube worms and seagrasses. To estimate the area of the seafloor covered by these assemblages, our approach was to map, photograph and sample them within a 0.34 $km^2$ region of the nearshore. The mapping was done acoustically. SCUBA divers, transported by underwater vehicles, traveled along a predetermined compass course within a specified area of the seafloor. Using a triad of moored, geopositioned, acoustic transponders (750 m range), each replying at a different frequency (25-32 kHz), and a

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



| 1. REPORT DATE | 2. REPORT TYPE | 3. DATES COVERED |
|---|---|---|
| **30 SEP 1997** | | **00-00-1997 to 00-00-1997** |

| 4. TITLE AND SUBTITLE | 5a. CONTRACT NUMBER |
|---|---|
| **Animal-sediment Interactions Relevant to Shallow-water Boundary-layer Flows and Sediment Transport** | 5b. GRANT NUMBER |
| | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER |
| | 5e. TASK NUMBER |
| | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,Department of Applied Ocean Physics and Engineering,Woods Hole,MA,02543** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR'S ACRONYM(S) |
| | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT **unclassified** | b. ABSTRACT **unclassified** | c. THIS PAGE **unclassified** | **Same as Report (SAR)** | **4** | |

diver-operated "interrogator" that determines the range to each transponder, surface-visible bottom features were waypoint mapped within the designated area. Ranging (range, time and channel) information was acquired at 0.5 Hz, stored in a computer carried on a diver's back, and processed in the laboratory. Calibration studies conducted during FY96 indicated greater than meter-scale accuracy of waypoint mapping using this system (Sisson et al., in prep.).

The field study was conducted in a high-energy nearshore region off the south shore of Martha's Vineyard Island, MA. This beach faces the open Atlantic Ocean where winds from the south and southeast have essentially unlimited fetch. Divers ran surveys approximately parallel and perpendicular to the shoreline, stopping to record ranges, take photographs and sample at each biologically interesting feature. Zero-visibility conditions limited the inshore depth of the surveys to 8 m, and the offshore depth (12 m) was defined by the range of the transponders. Preliminary surveys indicated that a maximum of ~500 m could be covered on a single dive, the actual distance depending on the frequency and complexity of the benthic biology. The survey period was ultimately limited by shiptime and weather. An approximately 650 m (cross shore) by 520 m (alongshore) region was surveyed twice, once in early July and once in early August. During each month, surveys spanned an ~10-day period.

## RESULTS

The offshore expression of this south-facing beach consisted of sands with shore-parallel ripples (wavelengths typically of 20-40 cm) interrupted by an ?100 m wide, shore-perpendicular mud belt (Fig. 1). During the study period, winds were primarily from the southwest, with stronger storm winds from the north. This direction was unusual for this time of year. Alongshore currents were dominated by a westerly component and were typically 10-20 cm/s with peaks exceeding 40 cm/s. Wave heights were typically 0.5-1 m, with storm waves exceeding 1.5 m. Storm waves were unusually small, however, as the study area is in the lee of the island when winds blow from the north.

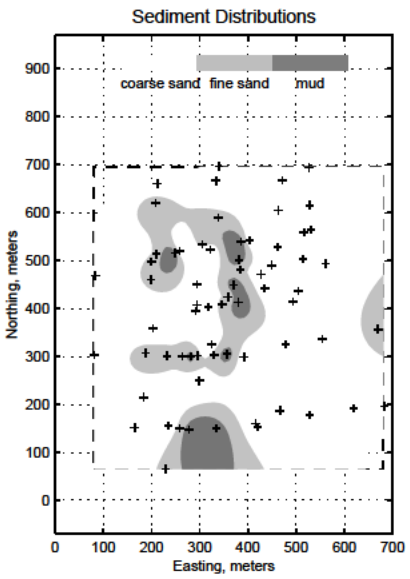


**Figure 1**. Contour plots, calculated from distance-inverse method, of categorical sediment data from July 1997. The beach is about 500 m north of the surveyed area.

The two organisms that occurred in high densities in this region were the sand dollar *Echinarachnius parma*, confined to sands, and the spionid tube worm *Spiophanes bombyx,* confined to the mud belt (Fig. 2). In fact, maintenance of the mud belt within this highly energetic nearshore area may be facilitated by mats of tube worms. Occurrences of sand dollars and tube worms were essentially non-overlapping, and some of the finer-scale (tens of meters) details of their distributions varied between July and August, presumably in response to fine-scale changes in the sediment distributions.

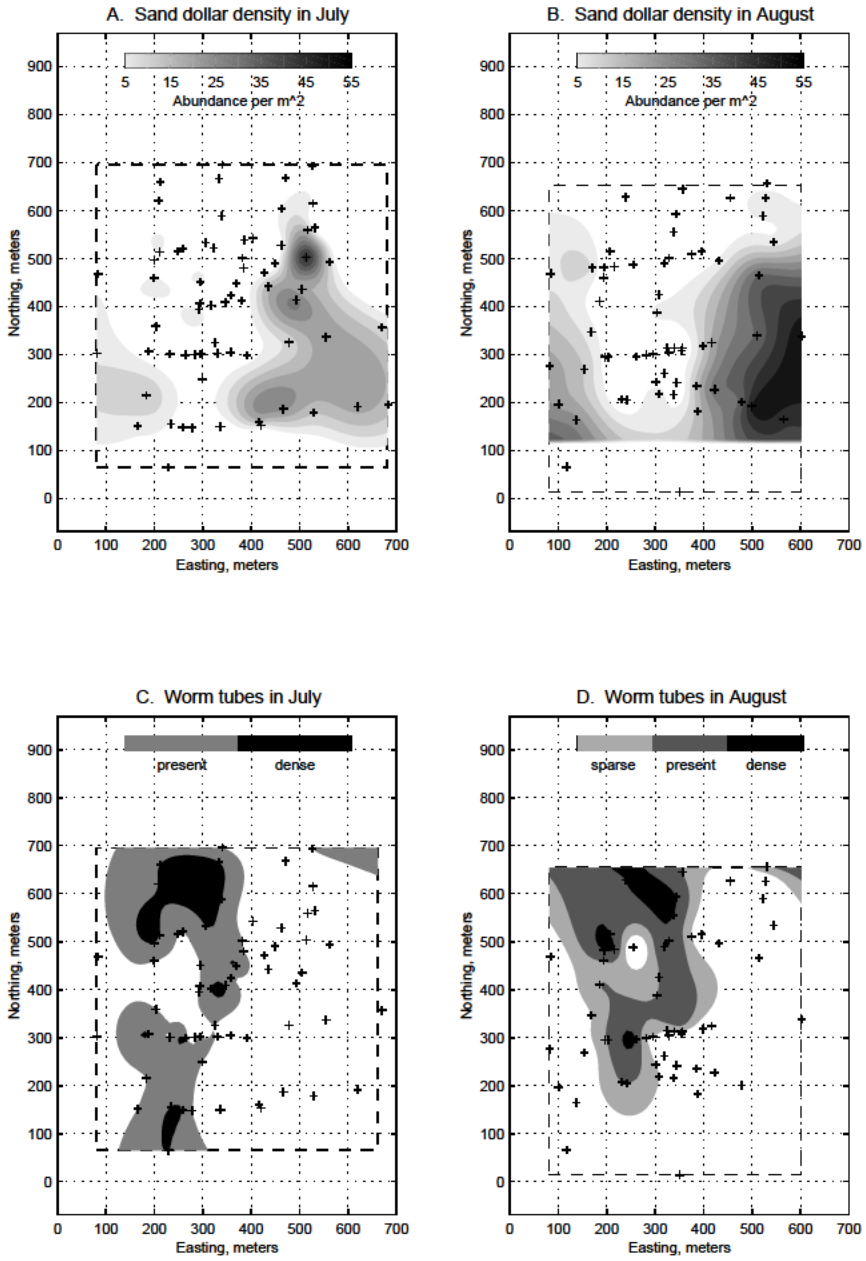


**Figure 2.** Contour plots, calculated from distance-inverse method, of sand dollar densities (A, B) and of categorical worm tube abundances (C, D) for July (left) and August (right) 1997. The beach is about 500 m to the north of the survey area.

# IMPACT

While sandy nearshore sediments have long been regarded as biological deserts, sedimentologists now concede that in offshore, muddy sediments benthic biology can sometimes have significant effects on sediment transport. A major goal of this study was to determine if the assumption is valid of biologically impoverished nearshore sands. Most biological surveys have focussed on intertidal beaches or subtidal areas that are not affected by the substantial wave action experienced on exposed, south-facing beaches such as our study site. In fact, the exposed, high-energy "inner

shelf”-- the region from a few meters depth to a few 10's of kilometers offshore -- is probably the most biologically and physically undersampled coastal environment. This study demonstrates that two species of relatively large, surface-visible benthic organisms live in sufficiently high abundances on the inner shelf to potentially affect sediment transport. Moreover, spatial resolution of 10's of meters clearly was necessary to document the boundaries of the mud belt and the association of tube worms with it. This kind of information should of of great interest to nearshore sedimentogists or oceanographers who assume that 1) high-energy nearshore areas consist of sands only (i.e., that mud patches could not persist in such physically reworked regions), and 2) there is no biology in sands or that what biology is present is very sparsely distributed.

## TRANSITIONS

The recent shift in focus of Naval operations from deep water to nearshore coastal regions has resulted in enhanced development of research programs on various aspects of mine countermeasures -- the detection, identification and neutralization of mines -- in depths from the beachface to “very shallow water” (10-40 m). Predicting the distribution of mines in such regions requires models that incorporate all relevant transport parameters. Thus, transitioning the results of this biological study to nearshore physical oceanographers and sedimentologists who use models to predict sand transport should enhance the accuracy of their model predictions, predictions which could be invaluable for a variety of mine countermeasures activities.

## RELATED PROJECTS

The results of this study should facilitate interpretation of the generality of point measurements used to predict sediment transport, such as those made during ONR’s SandyDuck Program.

## REFERENCES

Sisson, J.D., J. Shimeta, and C.A. Butman, in prep. A method for mapping surficial benthic assemblages with meter-scale resolution over kilometer-scale regions of the shallow subtidal. (for *Mar. Ecol. Prog. Ser.*)